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National Center for Radiological Health
Rockville, Maryland

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INSTRUMENT FOR MEASUREMENT OF X-RAY EMISSION FROM TELEVISION SETS

by

Richard K. Stoms & Edward Kuerze

Electronic Products Radiation Laboratory

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Technical Services Branch
National Center for Radiological Health
Rockville, Maryland 20852

FOREWORD

The survey instrument used by the National Center for Radiological Health to measure X-radiation from approximately 1200 color television receivers surveyed in the Washington, D. C. area is described in this report. It has the same basic design as the measuring equipment that was field-tested for the first time by the Center during a pilot survey made in November 1967 in Pinellas County, Florida.

The report contains details on the instrument's design, circuitry, operating characteristics and instructions. The instrument was designed by the Center's Electronic Products Radiation Laboratory for measuring X-rays as rapidly and as accurately as possible under field conditions.

We hope that the report will be useful to the industry and other official agencies who are planning future activities and programs relating to the control of radiation emissions from electronic products.

Donald J. Nelson, Jr.
Acting Chief, Technical Services Branch
National Center for Radiological Health

January 5, 1968

Instrument for Measurement of X-Ray Emission from Television Sets

by:

Richard K. Stoms and Edward Kuerze

January 5, 1968

Introduction

An instrument to determine X-ray emission from television sets was required to conduct a survey of a number of sets in owners' homes and distributors' stock (see picture attached).

The instrument must be capable of measuring the exposure rate listed in the NCRP recommendation which states "the exposure dose rate at any readily accessible point 5 cm. from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions".

The instrument must be portable and designed to obtain measurements rapidly and accurately under field conditions by health agency personnel.

As a result of the foregoing requirements, an instrument having the following general characteristics was designed and several were built by the Cincinnati, Ohio facility of Electronic Products Radiation Laboratory, TSB, NCRH:

Dimensions: 26-1/4" long, 4-1/2" wide, 1-1/2" thick

Weight: 3-1/2 lbs.

Sensing element: Six 1B85 GM tubes aligned to provide an active probe length of 16-1/2".

Readout: Linear meter and audio.

Power Supply: 12 volts at 22 mA (8 type AA penlight cells connected in series) and 9 volts at 0.7 mA (Eveready No. 222 or equivalent) stacked on top of the 12 volt supply.

Ranges: Full scale for 3000, 10,000, 30,000, and 100,000 for any one GM tube. (Circuitry automatically selects and gives reading for the GM tube with highest exposure rate.)

Time Constant: Operator selection of 1 and 5 seconds (approx.)

Note: [As a preliminary effort, a line voltage powered prototype instrument was designed and built. It consisted of six 1B85 tubes arranged so as to provide a probe with an active length of 16-1/2 inches. Circuitry was designed to automatically and continuously select and measure the pulse count rate of the GM tube with the highest exposure rate and display this count rate on a meter. In this circuit, the output pulses from the GM tube actuated a transistorized circuit that provided the conversion from count rate to a DC voltage or current that operated the meter movement.]

Description

Some redesign of the prototype was considered necessary to provide increased simplicity of calibration and construction. A battery type power supply was also considered to be of sufficient advantage as to warrant its inclusion.

The major change in the redesigned instrument from the prototype was the direct integration and measurement of the electrical current represented by the GM tube pulses rather than determining the

number of pulses per unit time by means of an electronic circuit. The instruments in the first group produced (including all instruments used in the Pinellas County, Florida study, November 1967) were given serial numbers "1" through "5". The instruments in the second group produced were given serial numbers "6" through "15". Some minor changes in the design of the electronic circuit were made in the second group. The differences between the two groups are discussed in Appendix I. All discussions and schematic diagrams of circuits given here refer to the second group, instruments "6" through "15".

Figures 1a, 1b, and 2 show the schematic diagrams of the main circuit, the high voltage circuit, and the audio circuit, respectively. In Figures 1a and 1b, Q8 is a constant current generator supplying a stable reference voltage for adjustment pots R14 and R20 which are used to equalize the steady state zero signal voltage at points b and c (about 3 volts). FET (field-effect transistor) Q4 and transistor Q5, and R26 make up what amounts to a source follower with the voltage at point b following the Q4 gate voltage. On all four ranges (3K, 10K, 30K and 100K full scale) the gate voltage is developed across the series combination of R12 and R13 shunted by capacitor C4 as a result of the electrical charge collected from the pulses in the 1B85 GM tube. The number of these pulses, and hence gate voltage, is related to the X-ray field incident on the 1B85. Originally, the prototype instrument was calibrated in thousands of counts per minute; for convenience, when the instrument was redesigned, the meter scales were kept the same, although readout is no longer in counts per minute.

Calibration resistor, R12 and R13, is a series combination of a 3.3 megohm resistor and 5 megohm potentiometer or a selected resistor between 3.3 and 6.8 megohm and a 1 megohm potentiometer, depending on availability of potentiometers. The pot is adjusted so that the base voltage range across the meter and its range resistor on the 3K range is 0.3 volts. Thus the 10K, 30K, and 100K ranges have a voltage range of 1.0, 3.0, and 10.0 volts full scale.

If voltages at b and c vary equal amounts in the same direction, there will be no meter deflection. If the gate of Q7 were made to follow the changes of point b, then point c would also follow these changes and the meter reading would not change. Time constant capacitor C5 is connected between point b and the Q7 gate and in conjunction with R17 determines the time constant. These capacitors allow relatively fast changes to couple to the Q7 base but not slow or DC voltages. It has been found convenient when using an instrument with an appreciable time constant to be able to occasionally revert to a fast response for a short time to allow the meter to assume its approximate reading and then return the instrument to its longer time constant. This is done by pressing the push button switch, SW 5, located on the front panel near the meter face. This shorts R17 reducing the time constant. Note that an additional "base" time constant is provided by R12 and R13 and C4.

Position 1 of range switch SW 3 is the "off" position. Position 2 causes the meter to read battery voltage under its normal load. Position 3 indicates operation of the high voltage supply. The meter current is a portion of the GV3A 900 volt shunt regulator current.

Any "on scale" reading indicates that there is shunt regulator current and that the high voltage supply is on and regulating. Note that in this position all circuits other than the HV are off (battery voltage being blocked by D4) thus there is no voltage at point c to obscure the meter reading. Position 4 is the zero check position. In this position the high voltage supply is disabled.

Positions 5 through 8 are the ranges previously described.

At this point, operation with only one GM tube has been considered. If in Figures 1a and 1b, six units identical to the sensor unit shown are paralleled and proper adjustments made, the meter will indicate only the current in the tube seeing the highest X-ray exposure rate. This comes about because the increase in voltage at point b due to an increase in gate voltage on one (or more) Q4 transistor will tend to cut off current through the remaining Q4, Q5 transistors. SW 1 is provided on each of the sensor units so that each unit may be zero set individually and also to facilitate trouble shooting.

GM tube No. 6 (tube farthest from meter) receives its high voltage directly from the HV supply while tubes 1 through 5 are supplied through push button switch, SW 2. Pushing SW 2 disconnects HV from 1 through 5 and discharges the stray capacity so that only tube No. 6 is operational. This is convenient in order to localize a beam or small area emitting X-rays. SW 2 must be kept depressed by the operator to deactivate tubes 1 through 5. When released, it is spring returned to normal.

The high voltage circuit shown in Figure 1b is fairly simple. A UJT (unijunction transistor), Q9, is operated as a relaxation

oscillator. The ramp voltage at the emitter of Q9 is capacitively coupled to the base of the normally off Q10. The result is a series of square wave current pulses through the primary of the UTC O-2 transformer. The frequency is approximately 2 kc. Use of the UJT oscillator provides a very reliable means of self starting as compared to the usual methods of feed back oscillators using a transformer tap.

The secondary circuit uses a standard voltage doubler and a GV3A 900 volt "Corotron"(1) shunt regulator. R34 is placed in series with the shunt regulator so that when SW 3 is in position 3, the meter will indicate a part of GV3A current.

Figure 2 shows how an audible signal is produced for a preselected X-ray level. Potentiometer, R1, is connected to point b of Figure 1a so that the emitter voltage of UJT, Q1, is related to X-ray exposure. R3 has been selected so that maximum setting of R1 will just barely keep Q1 from oscillating when the zero signal voltage at point b, Figure 1a, is present. Any increase in voltage at point b will increase emitter voltage at Q1 and cause oscillation. The frequency of oscillation is a function of emitter supply voltage which results in an increasing audio tone as X-ray exposure is increased. Q2 and Q3 comprise a monostable multivibrator. In its normal state, both Q2 and Q3 are off. A positive pulse from Q1 coupled into the base of Q2 will turn Q2 and Q3 on. Feedback network R9 and C3 provide the positive feedback required for monostable multivibrator action and control the "on" time. The speaker receives a pulse of energy for every pulse produced by Q1.

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(1) Registered trademark of Victoreen Instrument Company.

Operating Instructions

The range switch positions and functions are described on pages 4 and 5. The battery check position should show a reading of 21 volts. The batteries should be changed if the reading is 18 volts or lower.

Any "on scale" reading in the HV position of the switch indicates that the high voltage supply is operational.

Zero is checked by placing the range switch on the "zero" position. Adjustment is made with the screwdriver adjust pot below the meter face.

Most readings will be made with the time constant switch in "P" position (fastest time constant). The longer time constant may be selected if desired. When depressed, the red push button switch next to the time constant selector switch reduces the time constant to its shortest value. This can substantially reduce the time required for a reading.

The red push button switch labeled 6 is used to disable all GM tubes except the end one in the probe. This facilitates locating or defining the area of a beam.

An audible signal is incorporated and may be used at the operator's discretion. The sound is turned off by turning the audio control completely clockwise. Other positions of the control will determine the level or amount of X-ray exposure that the audio circuit will respond to. A radioactive check source emitting X-rays or gamma rays can be used to obtain any desired meter reading. The control can

then be set so that an audible signal can just be obtained. A decrease in X-ray exposure below this value will produce no sound. Increasing exposure over this level will result in a sound of increasing frequency. The sound is not that obtained by producing a click or sound pulse for every geiger tube pulse.

The time constant selector does not affect the response time of the audio signal which always operates on the shortest time constant.

Field Tests and Maintenance

A radioactive source emitting X-rays or gamma-rays can be used to check the operation of the instrument.

When the source is successively placed adjacent to the GM tubes, fairly consistent readings should be obtained. Differences in readings between tubes or between readings taken on both sides of the same tube are due to the fact that small variations in the short "source to tube" distance become important. These differences are minimal when the source is more than a few inches away as when measuring the field external to a television set.

If improper operation is indicated by the source check or a large change in the zero setting, the trouble can be isolated by means of switches mounted on the GM tube boards. Remove the screen on top of the instrument. If the trouble is one in which a high reading is obtained, the switches should be opened and closed successively until the one producing the malfunction is located. Usually the trouble will be due to dirt or excessive moisture on the GM tube mounting. If the trouble is not located in this manner, and cleaning and drying the tube

and mount does not correct the condition, proceed as described below.

In the event that the malfunction is indicated by a down scale reading or the above procedure has not corrected the condition, turn off all but one switch on the GM mounting boards. Set range switch on "zero" position. Set zero with the control below meter face. Turn switch off and another one on. Set zero with the 100K potentiometer on the mounting board. Turn this switch off and proceed with the next board, setting zero with the 100K potentiometer. When all units have been set to zero, turn all 6 switches on and, if required, set meter zero with control below meter face.

During initial adjustments and calibration in the laboratory, the front panel zero control is adjusted to produce a potential of between 2.6 and 2.8 volts at point "c" with all sensors switched off.

It is possible that the instrument will respond to light (especially ultra-violet) or strong electromagnetic fields. Light sensitivity is almost invariably caused by a defective light seal at the base of a GM tube. Recoating the glass seal with a light-tight coat of insulating material, such as a black silicone rubber, will eliminate this type of sensitivity.

In the event that operation without the perforated aluminum cover is required, or if an abnormally strong electromagnetic field is expected, the integrating capacitor C4 should be connected between the base of Q4 and ground on each of the GM tube circuit boards, and a 0.1 microfarad capacitor connected between the gate of Q7 and ground. This does not affect calibration or time constant.

SENSOR UNIT

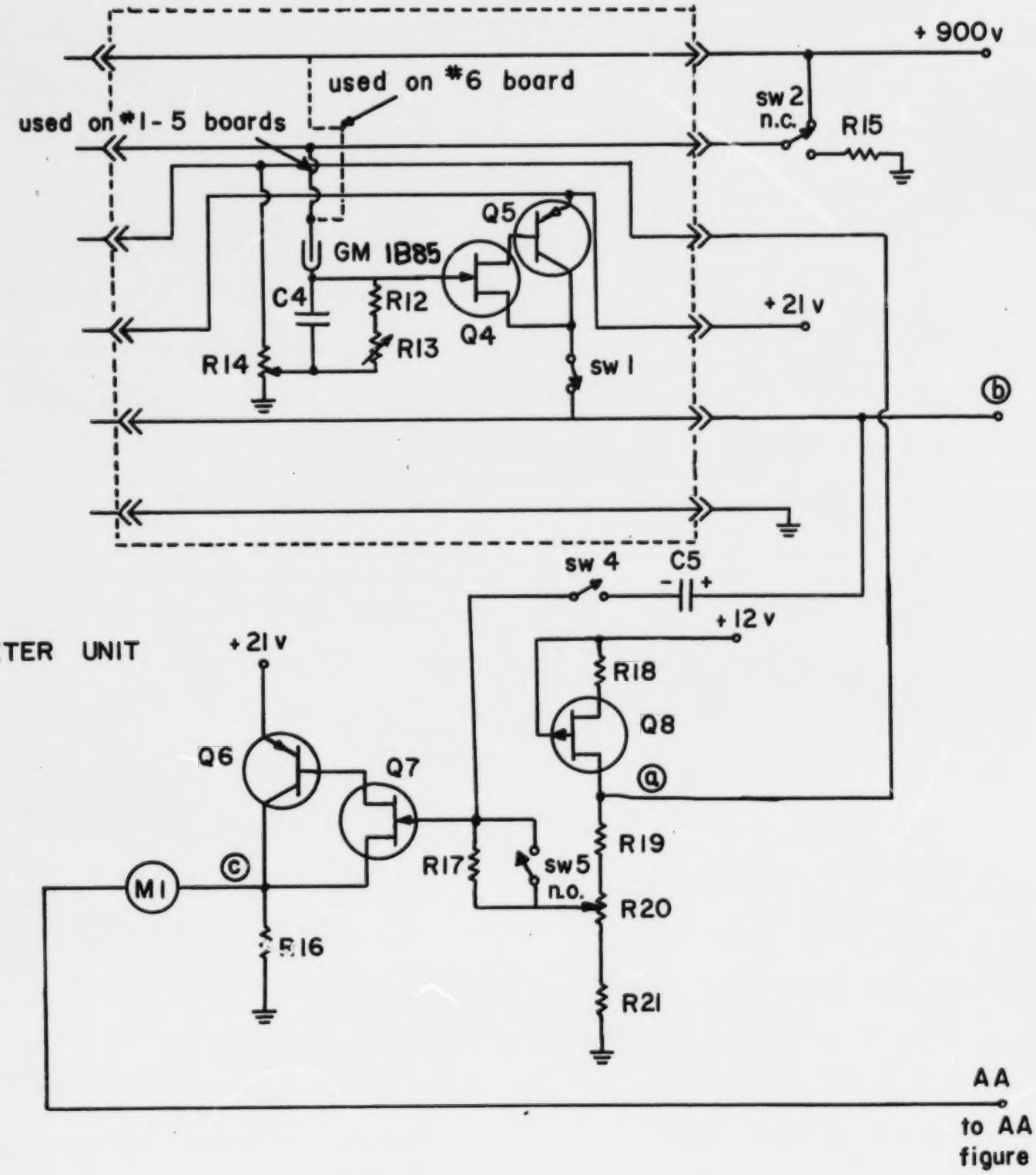


FIGURE 1a

Corrected 1/10/68

SELECTOR SWITCH & HIGH VOLTAGE CIRCUIT

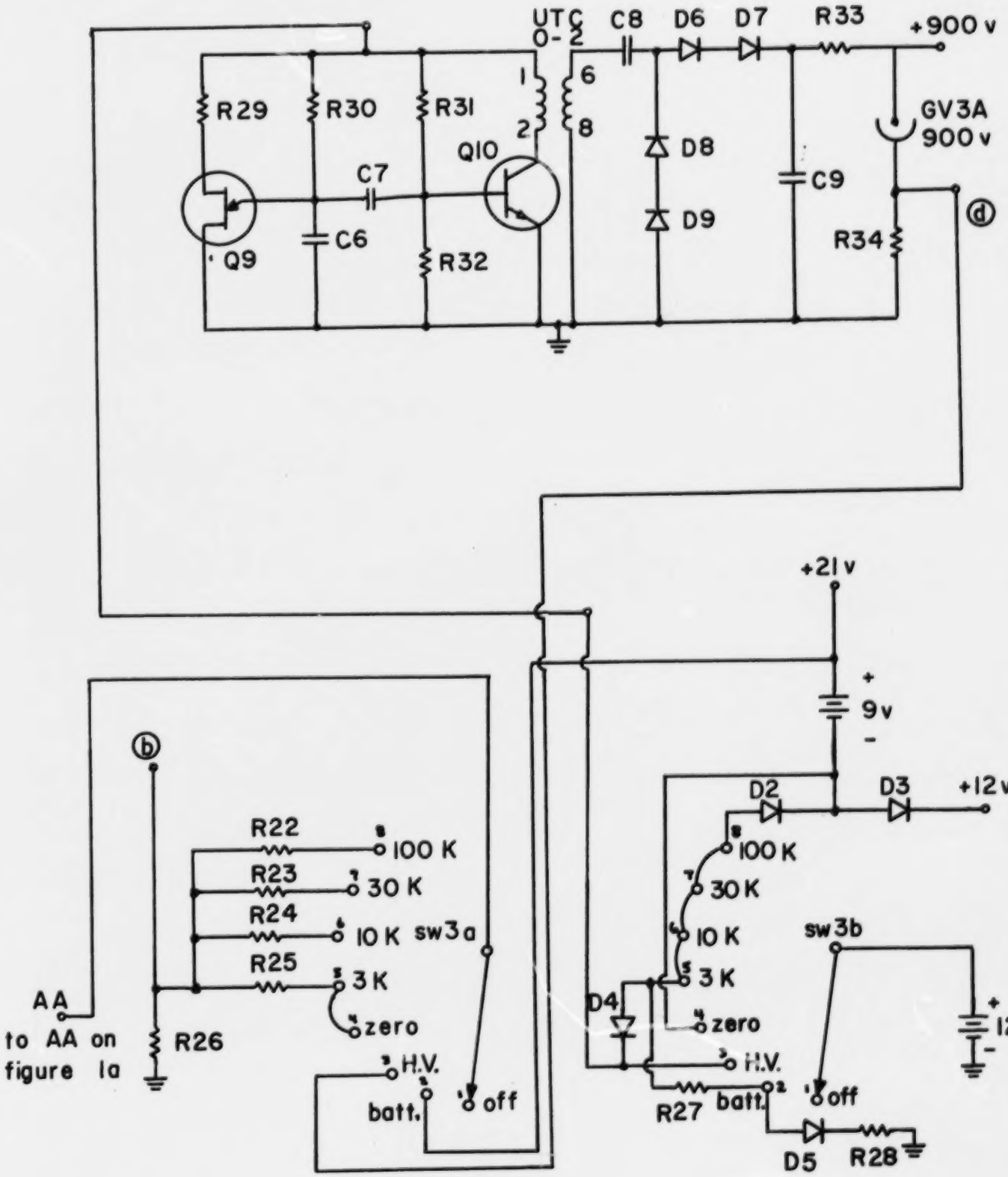
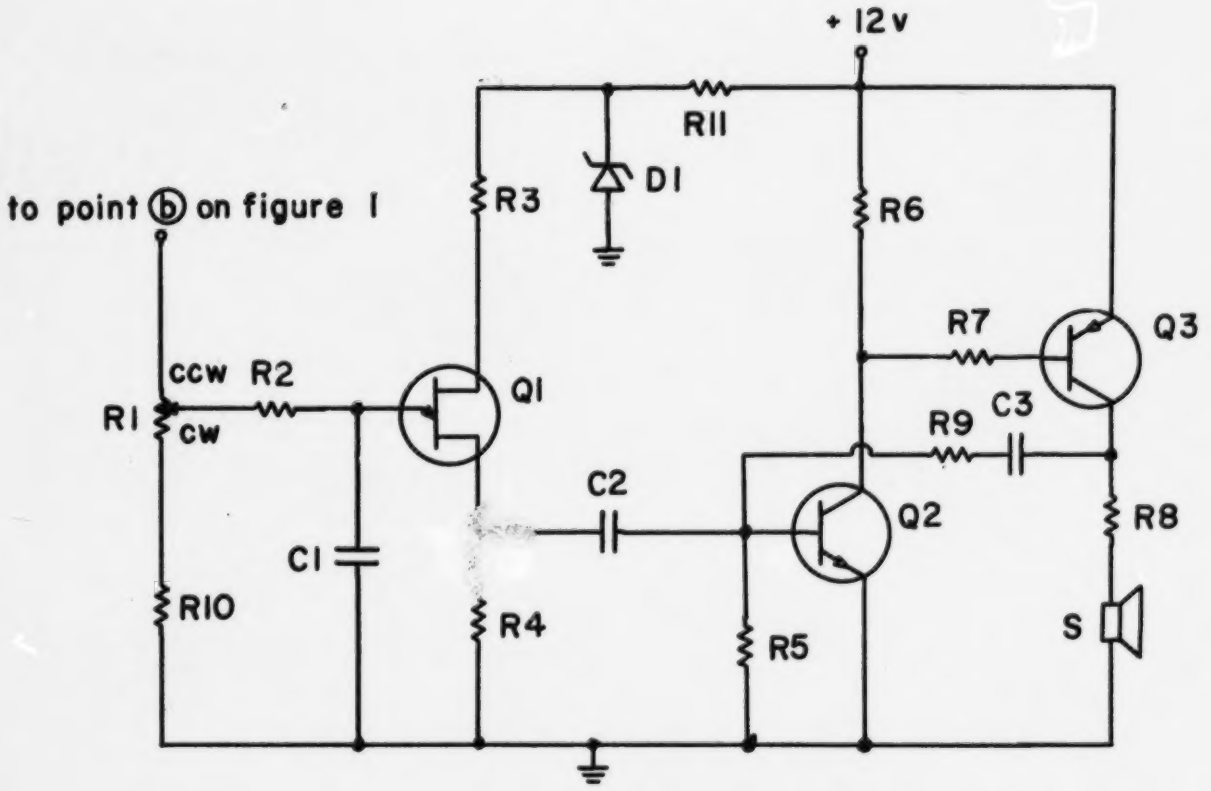


FIGURE 1b

AUDIO CIRCUIT



PARTS LIST

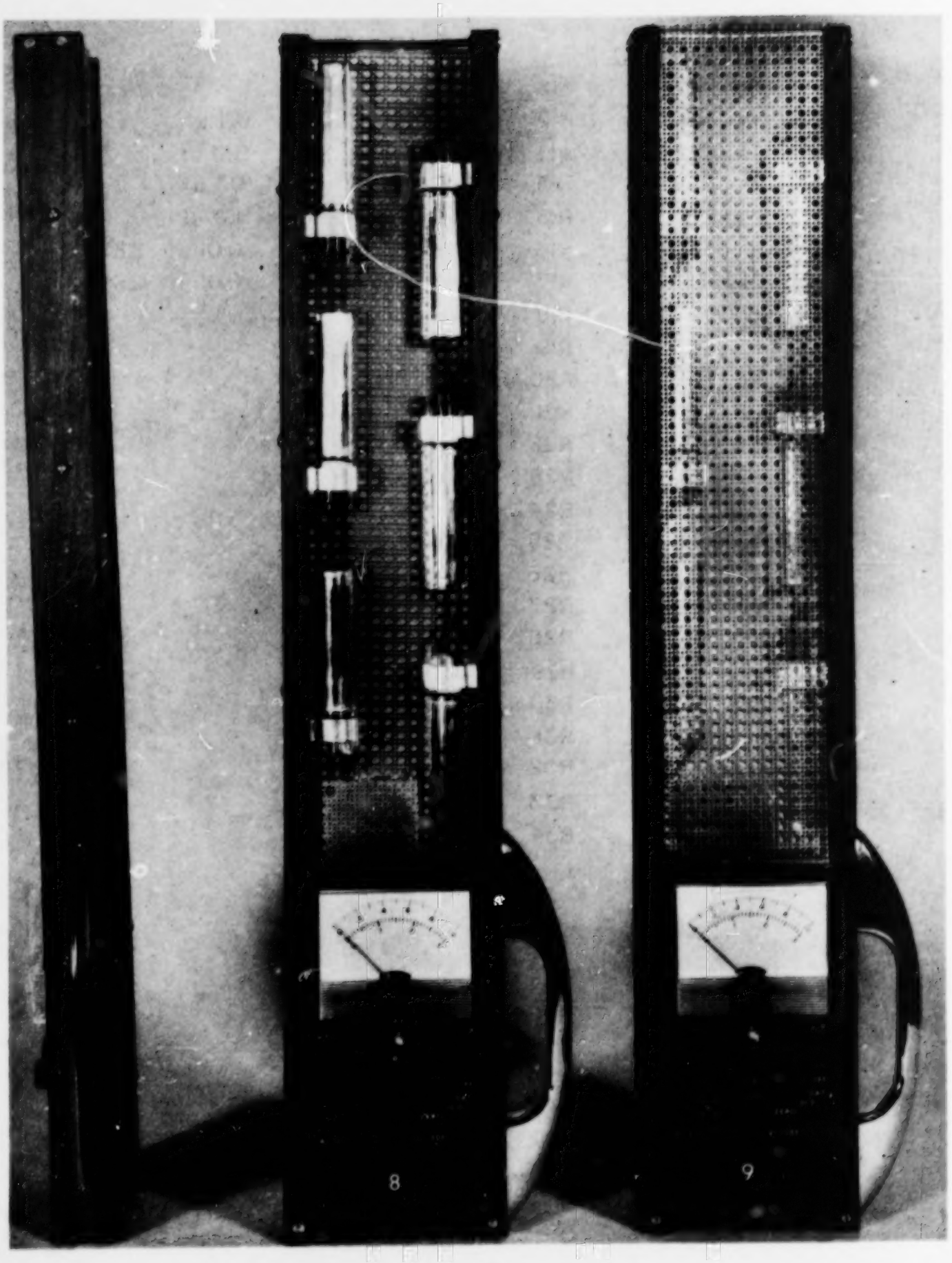
Q1	2N4852	R1	25 K	C1	.05 uf
Q2	2N3567	R2	220 K	C2	1.0 uf
Q3	2N3638	R3	*	C3	.01 uf
D1	IN754	R4	560		
S	8Ω speaker	R5	6.8 K		
		R6	1.0 K		
		R7	1.0 K		
		R8	47		
		R9	1.5 K		
		R10	3.3 K		
		R11	1.0 K		

* selected for sound threshold in zero x-ray field with R1 ccw

FIGURE 2

Parts List (cont'd.):

Q4	2N4221	R12	selected	C4	0.1 uf	
Q5	2N3638	R13	selected	C5	3.0 uf	
Q6	2N3638	R14	100 K	C6	0.1 uf	
Q7	2N4221	R15	4.7 M	C7	1.0 uf	
Q8	2N4360	R16	10K	C8	0.01 uf	2KV
Q9	2N1671B	R17	1.0 M	C9	0.01 uf	2KV
Q10	2N3567	R18	selected			
D2	F8	R19	22 K			
D3	F8	R20	25 K			
D4	F8	R21	22 K			
D5	F8	R22	selected			
		R23	selected			
		R24	selected			
		R25	selected			
		R26	10 K			
		R27	560 K			
		R28	560			
		R29	1.0K			
		R30	6.8 K			
		R31	47 K			
		R32	6.8 K			
		R33	10 M			
		R34	15 K			


8
9

Appendix I -- Circuit Differences in Instruments 1 through 5

The first group of instruments, serial numbers 1 through 5, had an 18 volt power supply with a drain of 22 mA consisting of two Burgess PM6 or equivalent 9 volt batteries in series. A correct reading in the battery check mode was 8 on the 10 scale.

These instruments had a 1 K full scale range. This required an extra transistor on the "Sensor Circuit" board and some slight changes in the range switch. The voltages at point b were 1, 3, and 10 volts above the fixed zero signal voltage of approximately 3 volts for 1 K, 3 K, and 10 K full scale, respectively. On the 30 K and 100 K full scale ranges two resistors were switched into a parallel combination with the calibration resistor (now the series combination of R 12 and R 13) by an FET providing a resistance reduction of 30:1. The 30 K and 100 K ranges then had full scale voltages of 1 and 3 volts, respectively, over the zero signal voltage.

Operation of these instruments was the same as for the second group with the exception of the absence of a separate position on the range switch for zero setting. The instruments are zeroed on the 30 K full scale range in a low radiation area.

These instruments had an additional switch selected time constant. The three were approximately 1, 3, and 10 seconds.